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Two-Area Load Frequency Control Using IP Controller Tuned Based on Genetic Algorithms

Sayed Mojtaba Shirvani Boroujeni, Babak Keyvani Boroujeni, Hamideh Delafkar and Elahe Behzadipour

Department of Electrical Engineering, Boroujen Branch, Islamic Azad University, Boroujen, Iran

Abstract: In this paper an optimal load frequency controller for two area interconnected power system is presented to quench the deviations in frequency and tie line power due to different load disturbances. In classical LFC problems, PI type controllers are used to control of system. But due to some disadvantages of the PI type controllers, the researches are toward finding a better control scheme. Although many different advanced method have been carried out to LFC problem, but the industries are willing to use simple PI controllers. In this scope, this paper presents IP type controller for LFC problem. The parameters of the proposed IP controller are tuned using Genetic Algorithms (GA) method. A two-area electric power system with a wide range of parametric uncertainties is given to illustrate the proposed method. To show effectiveness of the proposed method and also comparison purposes, a PI type controller optimized by GA is also designed. The simulation results visibly show the validity of IP controller in comparison with PI controller.

Key words: Load Frequency Control · Two Area Electric Power System · Genetic Algorithms · IP Controller

INTRODUCTION

For large scale electric power systems with interconnected areas, Load Frequency Control (LFC) is important to keep the system frequency and the inter-area tie power as near to the scheduled values as possible. The input mechanical power to the generators is used to control the frequency of output electrical power and to maintain the power exchange between the areas as scheduled. A well designed and operated power system must cope with changes in the load and with system disturbances and it should provide acceptable high level of power quality while maintaining both voltage and frequency within tolerable limits.

Many control strategies for Load Frequency Control in electric power systems have been proposed by researchers over the past decades. This extensive research is due to fact that LFC constitutes an important function of power system operation where the main objective is to regulate the output power of each generator at prescribed levels while keeping the frequency fluctuations within pre-specifies limits. A unified tuning of PID load frequency controller for power systems via internal mode control has been proposed in [1]. In this paper the tuning method is based on the two-degree-of-freedom (TDF) internal model control (IMC) design method and a PID approximation procedure. A new discrete-time sliding mode controller for load-frequency control in areas control of a power system has been presented [2]. In this paper full-state feedback is applied for LFC not only in control areas with thermal power plants but also in control areas with hydro power plants, in spite of their non minimum phase behaviors. To enable full-state feedback, a state estimation method based on fast sampling of measured output variables has been applied. The applications of artificial neural network, genetic algorithms and optimal control to LFC have been reported in [3-5]. An adaptive decentralized load frequency control of multi-area power systems has been presented [6]. Also the application of robust control methods for load frequency control problem has been presented by [7-8].

This paper deals with a design method for LFC in a multi area electric power system using IP type controller Swhose parameters are tuned using GA. In order to show effectiveness of the proposed method, this IP controlleris

Corresponding Author: Sayed Mojtaba Shirvani Boroujeni, Department of Electrical Engineering, Boroujen Branch, Islamic Azad University, Boroujen, Iran, P.O. Box: 88715/141.
Tel: +983824223812, Fax: +98983824223812.

compared with a PI type controller whose parameters are tuned using GA. Simulation results show that the IP controller guarantees robust performance under a wide range of operating conditions and system uncertainties.

Plant Model: Fig. 1 shows a two-control area power system which is considered as a test system. The state-space model of the system is as (1) [9].

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx \end{cases} \tag{1}$$

Where:

$$u = \left[\Delta P_{D1}, \Delta P_{D2}, U_1, U_2\right]$$
$$y = \left[y_1, y_2\right] = \left[\Delta f_1, \Delta f_2, \Delta P_{tie}\right]$$
$$x = \left[\Delta P_{G1} \quad \Delta P_{T1} \quad \Delta f_1 \quad \Delta P_{tie} \quad \Delta P_{G2} \quad \Delta P_{T2} \quad \Delta f_2\right]$$

$$A = \begin{bmatrix} \frac{-1}{T_{G1}} & 0 & \frac{-1}{r_1 T_{G1}} & 0 & 0 & 0 & 0 \\ \frac{1}{T_{T1}} & \frac{-1}{T_{T1}} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{M_1} & \frac{-D_1}{M_1} & \frac{-1}{M_1} & 0 & 0 & 0 \\ 0 & 0 & T_{12} & 0 & 0 & 0 & -T_{12} \\ 0 & 0 & 0 & 0 & \frac{-1}{T_{G2}} & 0 & \frac{-1}{r_2 T_{G2}} \\ 0 & 0 & 0 & 0 & \frac{1}{T_{T2}} & \frac{-1}{T_{T2}} & \\ 0 & 0 & 0 & \frac{1}{M_2} & 0 & \frac{1}{M_2} & \frac{-D_2}{M_2} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 & \frac{1}{M_1} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{M_2} \\ \frac{1}{T_{G1}} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{T_{G2}} & 0 & 0 \end{bmatrix}$$

The parameters of model, defined as follow:

Δ: Deviation from nominal value
M=2H: Constant of inertia
D: Damping constant
R: Gain of speed droop feedback loop
T_t: Turbine Time constant

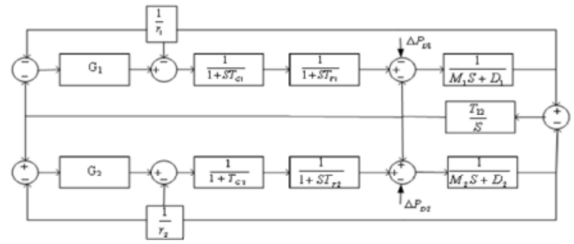

Fig. 1: Two-area electric power system for LFC studies

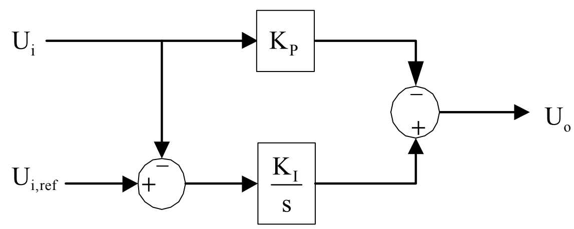

Fig. 2: Structure of the IP controller

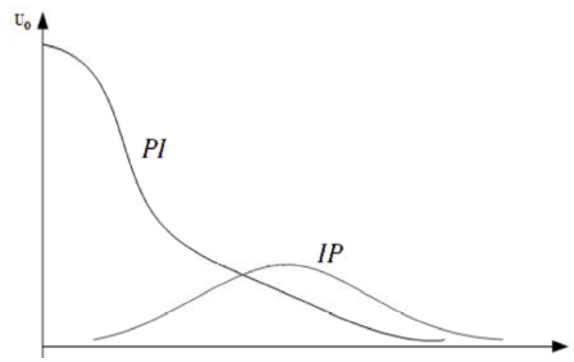

Fig. 3: Output of IP and PI regulators with the same damping coefficient (ξ = 1) and the same band width at the same step input signal command

T_G: Governor Time constant
G_1: First area controller
G_2: Second area controller

- The typical values of system parameters for nominal operation condition are as follow:

$$T_{T1} = T_{T2} = 0.03 \qquad T_{G1} = T_{G2} = 0.08$$
$$T_{P1} = T_{P2} = 20 \qquad R_1 = R_2 = 2.4$$
$$K_{P1} = K_{P2} = 120 \qquad B_1 = B_2 = 0.425$$
$$K_1 = K_2 = 1; a_{12} = -1 \qquad T_{12} = 0.545$$

Where, the footnote 1 indicates first area parameters and footnote 2 indicates second area parameters and the parameters of two areas are considered equal.

The objectives are Design G_1 and G_2 in Load Frequency Control (LFC). As referred before, many methods have been carried out to design these controllers so far. In this paper IP type controller is considered to control of system. A Meta heuristic optimization method named GA is used to tuning the proposed controllers. The goals are study the ability of IP controller in Load Frequency Control (LFC) problem and also comparing the performances of IP and PI controllers. In the next section, the proposed IP controller is developed.

IP Controller: As referred before, in this paper IP type controllers are considered for LFC problem. Fig. 2 shows the structure of IP controller. It has some clear differences with PI controller. In the case of IP regulator, at the step input, the output of the regulator varies slowly and its magnitude is smaller than the magnitude of PI regulator at the same step input [10]. Also as shown in Fig. 3, If the outputs of the both regulators are limited as the same value by physical constraints, then compared to the bandwidth of PI regulator the bandwidth of IP regulator can be extended without the saturation of the regulator output [10].

Design Methodology: The proposed IP controller performance is evaluated on the proposed test system given in section 2. The parameters of the IP controllers are obtained using GA. In the next subsection a brief introduction about GA is presented.

Genetic Algorithms: Genetic Algorithms (GA) are global search techniques, based on the operations observed in natural selection and genetics [11]. They operate on a population of current approximations-the individuals-initially drawn at random, from which improvement is sought. Individuals are encoded as strings (Chromosomes) constructed over some particular alphabet, e.g. the binary alphabet {0.1}, so that chromosomes values are uniquely mapped onto the decision variable domain. Once the decision variable domain representation of the current population is calculated, individual performance is assumed according to the objective function which characterizes the problem to be solved. It is also possible to use the variable parameters directly to represent the chromosomes in the GA solution. At the reproduction stage, a fitness value is derived from the raw individual performance measure given by the objective function and used to bias the selection process. Highly fit individuals will have increasing opportunities to pass on genetically important material to successive generations. In this way, the genetic algorithms search from many points in the search space at once and yet continually narrow the focus of the search to the areas of the observed best performance. The selected individuals are then modified through the application of genetic operators. In order to obtain the next generation Genetic operators manipulate the characters (genes) that constitute the chromosomes directly, following the assumption that certain genes code, on average, for fitter individuals than other genes. Genetic operators can be divided into three main categories: Reproduction, crossover and mutation [11].

Table 1: Optimum values of K_P and K_I for IP controllers

	K_P	K_I
First area IP parameters	3.3450	7.5632
Second area IP parameters	1.7237	8.1946

Table 2: Optimum values of K_P and K_I for PI controllers

	K_P	K_I
First area PI parameters	1.8567	5.3619
Second area PI parameters	3.1946	4.0329

IP Controller Adjustment Using GA: In this section the parameters of the proposed IP controllers are tuned using GA. In optimization methods, the first step is to define a performance index for optimal search. In this study the performance index is considered as (2). In fact, the performance index is the Integral of the Time multiplied Absolute value of the Error (*ITAE*).

$$\mathrm{ITAE} = \int_0^t t\left|\Delta\omega_1\right|dt + \int_0^t t\left|\Delta\omega_2\right|dt \qquad (2)$$

It is clear to understand that the controller with lower ITAE is better than the other controllers. To compute the optimum parameter values, a 10 % step change in ΔP_{D1} is assumed and the performance index is minimized using GA. The following genetic algorithm parameters have been used in present research.

- Number of Chromosomes: 4
- Population size: 24
- Crossover rate: 0.5
- Mutation rate: 0.1

It should be noted that GA algorithm is run several times and then optimal set of parameters is selected. The optimum values of the IP parameters are obtained using GA and summarized in the Table 1.

In order to comparison and show effectiveness of the proposed method, PI type controller optimized by GA is incorporated for LFC. The optimum value of the PI controllers Parameters are obtained and summarized in the Table 2.

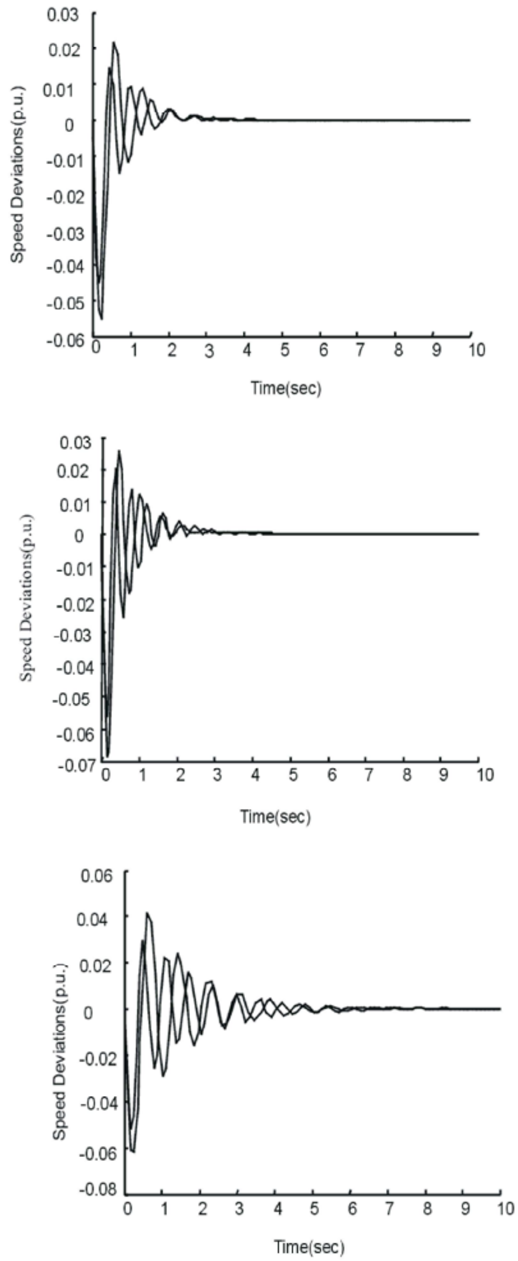

Fig. 4: Dynamic response $\Delta\omega 1$ following step change in demand of first area ($\Delta PD1$)
a: Nominal b: Heavy c: Very heavy

Table 3: 10% Step increase in demand of first area (ΔĐ$_{D1}$)

	The calculated ITAE	
	IP	PI
Nominal operating condition	0.0265	0.0365
Heavy operating condition	0.0306	0.0384
Very heavy operating condition	0.0571	0.0780

RESULTS AND DISCUSSIONS

The results are carried out on the multi area test system with the proposed IP and PI controllers. Three operating conditions are considered for simulation as follows:

- Nominal operating condition
- Heavy operating condition (20% changing parameters from their typical values)
- Very heavy operating condition (40% changing parameters from their typical values)

In order to demonstrate the robustness of the proposed method, The *ITAE* is calculated following step change in the demand of first area (ΔP_{D1}) at all operating conditions (Nominal, Heavy and Very heavy) and results are listed at Table 3. Following step change, the IP controller has better performance than the PI controller at all operating conditions.

Fig. 4 shows $\Delta\omega_1$at nominal, heavy and very heavy operating conditions following 10 % step change in the demand of first area (ΔP_{D1}). Each figure contains two plots as solid line for IP controller and dashed line for PI controller. It is seen that the IP controller has better performance than the other method at all operating conditions.

CONCLUSIONS

This paper presented the application of a new control scheme for LFC problem. IP type controller has been successfully carried out for LFC problem. The parameters of the proposed IP controller have been tuned by using GA. The proposed IP controller had significant priority rather than PI controller. The simulation results which have been carried out on a two-area electric power system showed the viability of IP controller. The PI controller is the most commonly used controller in the industry and practical systems, therefore the paper's results can be used for the practical LFC systems.

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